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THE EXISTENCE, IN COSMIC RAYS, OF POSITIVE
AND NEGATIVE PARTICLES WITH MASSES GREATER THAN THE MESON'S

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[A Digest]

From 1942 to the present, cosmic rays have been thoroughly studied on Mt Alagez, elevation 3,250 meters. The soft component of cosmic rays were especially investigated. All these studies demonstrated that the soft component could not be explained by electrons, photons, or mesons alone (Alikhanov and Alikhanyan, J. of Phys. 8, 314, 1944; Nikitin et al, J. of Phy. 9, 167, 1945; Landau, J. of Phy. 8, 201, 1944; Vaysenberg. et al, J. of Phy. 10, 294, 1946).

Thus, the soft component of cosmic rays had to contain a new particle. Experiments in ionization first showed it to be nonelectronic in property. These experiments revealed a mass 0.8 - 1.4 times the mass of the proton, and therefore the new particle was at first thought to be merely a proton of 100 - 200 Mev energy. But further studies, especially with the aid of the large magnet at Mt Alagez, revealed that these new heavy particles must possess both positive and negative charges.

This last and startling phase is discussed in the following report, which is the first published work on the nature of the charge of the new heavy particle found in the soft component of cosmic rays. A discussion of the method employed to study the new particles follows:

Method

The method used in cosmic ray studies at Mt Alagez is new and has many unusual features; therefore, it deserves a detailed description. It involves an apparatus for analyzing cosmic rays by magnetic deflection. The apparatus consists of an

CONFIDENTIAL

- 1 -

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50X1-HUM

ordinary "telescope" of three vertical rows of counters, I, II, III, and of a permanent magnet producing a uniform field between row I and III. The counters are arranged parallel to the field direction in the gap of the magnet.

The counters operate an electronic system in such a way that discharge coincidences in counters of rows I, II, III, caused by particles passing through the telescope, are exactly registered and thus it is known through which counters the particles passed. This is achieved by connecting electronically each counter to a neon-flashing bulb on a special panel. Thus the passage of a particle through the telescope flashes the proper neon bulbs of the counters through which the particle passed. These flashes are continuously photographed on motion picture film. This method was developed by S. Ya. Nikitin.

The pulse of a particle is easily determined from its deflection in the magnetic field, which deflection in turn is readily found from the history of the particle's passage recorded by the flashes. Rows I, II, III, were connected in a "coincidence system"; absorbers of various thicknesses are placed between rows III and IV. Thus a particle's deflection and track can be simultaneously measured. Five to 6 centimeters of lead between III and IV serve to separate the soft component from the hard, and at the same time the pulse distribution of both components can be photographed.

The trajectory of a charged particle in a uniform magnetic field is helical of course. A simple mathematical analysis of this trajectory was made and applied to the problem of pulse determination. Pulse is measured in units of ev/c and $H - 3,840$ oersteds. A peculiar quantity, called "candle power" S , had to be determined for the apparatus. "Candle power" is defined as the number of combinations of counters effecting deviation.

Deviation of particles is measured by the apparatus with different effectiveness or efficiency, depending upon the magnitude of deviation. Since large deviations are measured by a smaller number of combinations of counters and small deviations are measured by a large number of possible combinations, the system is thus less sensitive to large deviations than to small ones. This explains the need for the above-mentioned candle power, for which much study and graphs were needed.

The method, of course, is affected by so-called "accidental" or chance coincidences. All possible other errors were carefully listed and their effects measured. Formulas and graphs are given for relating errors in determination of particle coordinates, probability of scatter by walls or magnetic field, secondary particles, and accidental coincidences.

The counters used were self-quenching ones, filled with argon (90 percent) and alcohol vapor (10 percent of pressure). They were placed in unsoldered glass cylinders and had a copper cathode. Counting began at 900 volts, the "plateau" width was: 150 - 200 volts. A total of 70 - 80 counters were always in operation.

The electronic system operating the counters and bulbs was fully developed, as shown by the block-schematic diagram of the apparatus. The diagram shows magnet, rows, individual counters, amplifiers, motion picture apparatus, neon bulbs, panel, master pulse block, and wiring circuits.

The flashes from the neon bulbs were photographed on panchromatic motion picture film with a "Xinamo" motion picture apparatus. The frame was moved after each master pulse. A total of 12,000 frames were taken.

CONFIDENTIAL

- 2 -

CONFIDENTIAL

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Results

The minimum pulse measured was $0.7 \cdot 10^8$ ev/c. As mentioned, 12,000 photographs were taken for various lead-filter thicknesses and arrangements, shown fully in tables and figures. Usually, the soft component was separated from the hard component by a 5.4-centimeter lead-filter between rows III and IV. Various filter arrangements were employed to separate electrons, mesons, or protons by inserting various thickness of lead between the various rows besides III and IV.

The spectrum of the hard component was obtained. The hard component which was comprised at times of mesons and electrons traversed 5.4 centimeters of lead. Spectra of meson and electron pulses were also obtained and are shown in tables and graphs according to deviation (centimeters), number of trajectories (positive and negative), and candle power (in percent).

The data permitted obtaining the meson mass, which was found to be:
 $M = (220 \pm 40)m_e$ (where m_e is the electron mass).

Besides the major interest in the sign of the charge of the new particle, shown to be both positive and negative, other data was collected, especially in connection with the problem of accidental coincidences. Thus, 5,640 combinations of counters resulted to give all possible deviations. It was found that one combination per hour gave 0.33/5640 "accidental coincidences." As for the number of accidental coincidences corresponding to a given deviation, 1,230 combinations produced deviations of 10 - 23 centimeters.

The experimental results given an excellent opportunity to check the various avalanche theories. Good agreements were found for Belen'kiy's and Landau's theories of cascade showers. Tables and graphs are used to illustrate the agreement.

Conclusion

Magnetic analysis of cosmic ray soft component at an elevation of 3,250 meters showed that cosmic showers must contain particles with both positive and negative signs, with masses greater than the meson masses. Exact determination of the new particle's mass was found to be impossible, not because of inaccuracies in determining the particle's pulse and range, but because of the diversity of masses. Thus, at least three different masses were found, among them masses greater than the proton mass.

Bethe's detailed study of the errors in determination of meson masses was vitiated by his use of faulty experimental data of various authors.

Conjectures were made regarding the variatron and its transformation into the meson.

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- 3 -

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